Technology Development of ACP100, User Requirements of INPRO Experience

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DRAFT

CONTENTS

- ***Technical Aspects --Introduction of ACP100***
- ***User Requirements of INPRO Experience***

Technical Aspects

Introduction of ACP100

- CNNC SMR, code ACP100, is an innovative PWR based on existing PWR technology , adapting “passive” safety system and “integrated” reactor design technology;
- No operator intervention needed in 72 hours of accident ;
- Passive severe accident prevention and mitigation action, such as for containment hydrogen eliminator, cavity flooding etc. to ensure the integrity of pressure containment;
- The modular design technique is easy to control the product quality and shorten the site construction period.

Technical Aspects

Main design parameters

ACP100

Thermal power	*310MWt*
Electrical power	*~100MWe*
Design life	*60 years*
Refueling period	*2 years*
Coolant inlet temperature	*282 ℃*
Coolant outlet temperature	*323 ℃*
Coolant average temperature	*303 ℃*
Best estimate flow	*6500 m^3/h*
Operation pressure	*15MPaa*
Fuel assembly type	*CF2 shortened assembly*
Fuel active section height	*2150 mm*
Fuel assembly number	*57*

Technical Aspects

Main characteristics

(1) Primary system and equipment integrated layout. The maximal size of the conjunction pipe is 5-8 cm, whereas the large PWR is 80-90cm.

(2) Large primary coolant inventory.

(3) Small radioactivity storage quantity. Total radioactivity of SMR is 1/10 of large PWR's, meanwhile multi-layer barrier is added to keep the accident source-term at a low level.

(4) Vessel and equipment layout is benefit for natural circulation.

Technical Aspects

Main characteristics(continued)

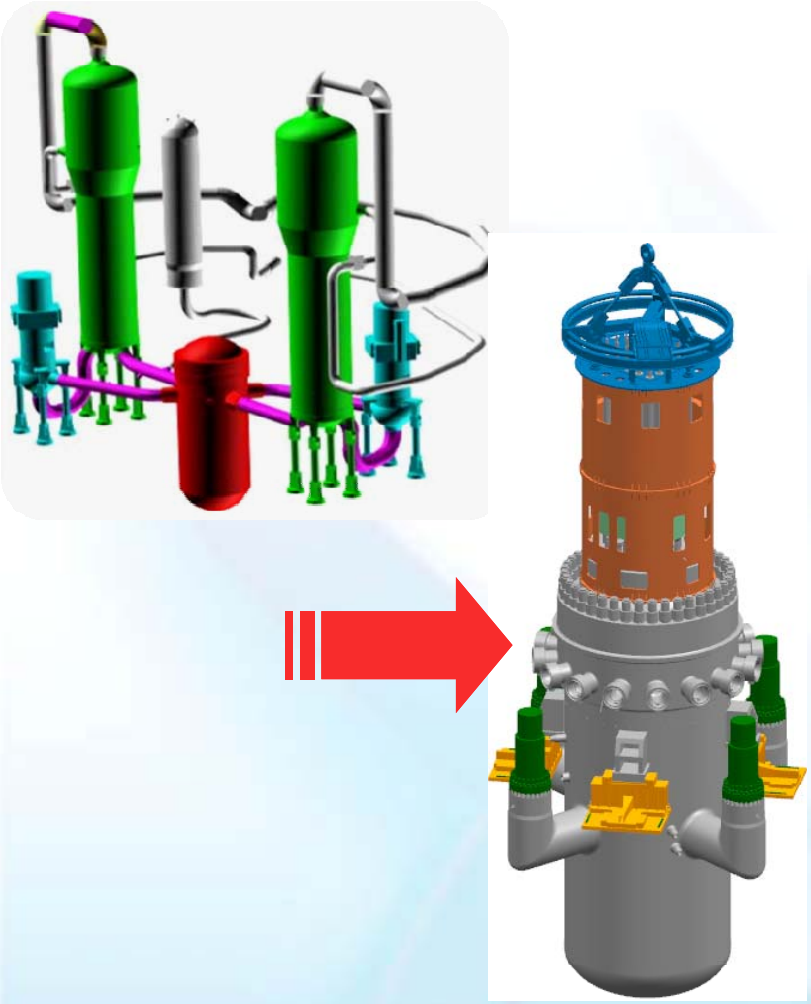
(5) Assurance decay heat removal more effectively. 2-4 times of the efficiency of large PWR heat removal from the vessel surface.

(6) Smaller decay thermal power. 1/5-1/10 times of decay thermal power comparing that of large PWR after shutdown, and is easier to achieve safety by the way of “passive”.

(7) Reactor and spent fuel pool lay under the ground level for better against exterior accident and good for the reduction of radioactive material release.

Technical Aspects

Nuclear steam supply system



ACP100

- Integrated layout instead of loop type
- Main pump and reactor pressure vessel connected by short pipe
- Steam generator sets in reactor pressure vessel
- Nuclear steam supply system integrated to reactor module
- CRDM, pressure vessel, reactor internals, OTSG, and canned motor pump all mature technology

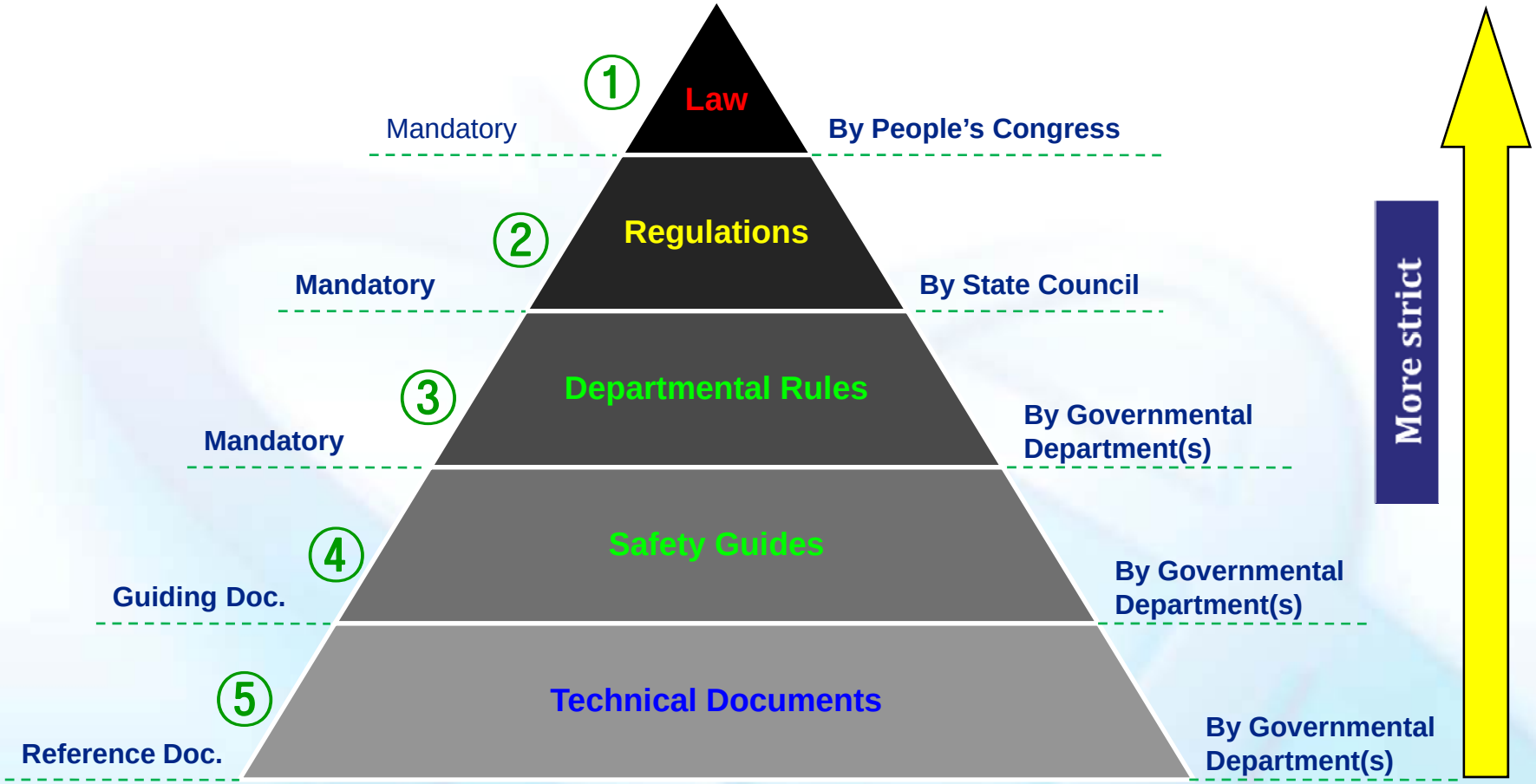
Codes and Standards applied by ACP100 (1/2)

The design of ACP100 totally meet the requirements of nuclear laws and regulations in china. The nuclear safety laws, codes, regulations and standards used in china is divided into 5 different levels.

- *Level 1, Laws - Issued by the Congress (mandatory).*
- *Level 2, Codes and Regulations - Issued by the State Council (mandatory). Setting up administrative scope, principles, organizations and its' functions etc；*
- *Level 3, Departmental Rules - Issued by governmental organizations (mandatory). Defining the implemental methods based on the Regulations. Setting up nuclear safety objectives and basic requirements； (NNSA)*
- *Level 4, the Guides - Issued by the Governmental organizations (recommendatory). Recommending the methods or procedures to satisfy the safety requirements；*
- *Level Technical documents-Issued by 5, the Governmental organizations (referential).*

Technical Aspects

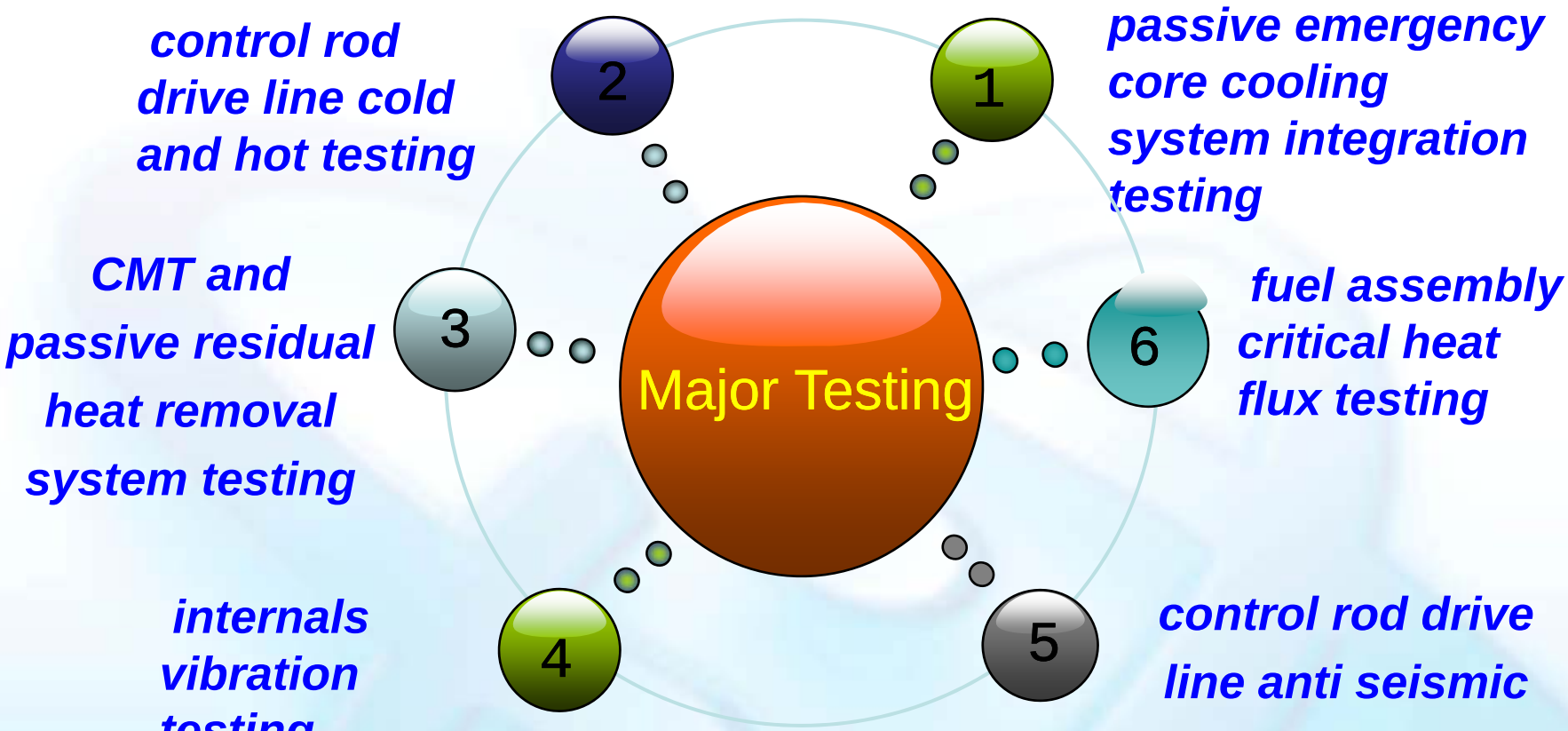
Codes and Standards applied by ACP100 (2/2)



All major equipment are localized design and manufactured local potential supplier:

- ***Reactor vessel potential supplier: China Yizhong Group, China Erzhong Group, Dongzhong Group***
- ***Canned pump: Habin Electrical Group, Dongfang Electrical Group***
- ***Reacter internal: Dongfang Wuhan Co. , Shanghai No.1 machine tool Co.***
- ***Control Rod Drive Mechanishm: Shanghai No.1 machine tool Co., Sichuan Huadu Co.***
- ***SCF2 fuel assembly: CNNC Yibin Fuel Assembly Co.***
- ***10Mwe stem turbine: Habin Electrical Group, Dongfang Electrical Group, Shanghai Electrical Group***

All major validation testing facilities and testing are localized



licensing status of ACP100 in China

- ***Signed a contract of SMR combined research with National Nuclear & Radiation Safety Center in 2011, and developed the following works:***

National Nuclear & Radiation Safety Center gave the comments on the SMR research report of design preparation phase;

Had a technical exchange of SMR containment design after Fukushima nuclear accident;

Passive integration test research technical exchange, and the test program was approved;

Completed the Q1 questions and question reply of concept design stage, and the concept design was approved;

Sign several specific research programmers and standard design safety analysis combined research with National Nuclear & Radiation Safety Center in year 2013.

licensing status of ACP100 in China: Challenge

- *Multiple modules per site*

In China, National standard GB 6249-2011 'Regulation for environmental radiation protection of nuclear power plant' gives the radiation discharges for a single unit nuclear power plant. For multiple reactors in same site , it requires the radiation discharges cannot exceed 4 times than that of single unit nuclear power plant.

Thus cause a problem for SMR due to multiple units on the same sites, sometimes more than 10 SMR units on the same sites.

We suggests to use total radiation discharges for per site than that of per units or several units.

licensing status of ACP100 in China: Challenge

- *Emergency planning zone*

Historically , Emergency planning zone have been set based on conservative approaches to calculating bounding individual dose rate subsequent to a postulated accident sequence. The zones are ranging up to 10 miles.

In China, the range is 7 to 10 kilometers.
However, SMRs are designed for local grid and non electrical application, such as district heating, desalination.

Reduction of Emergency planning zone is essential important for SMR's future deployment.

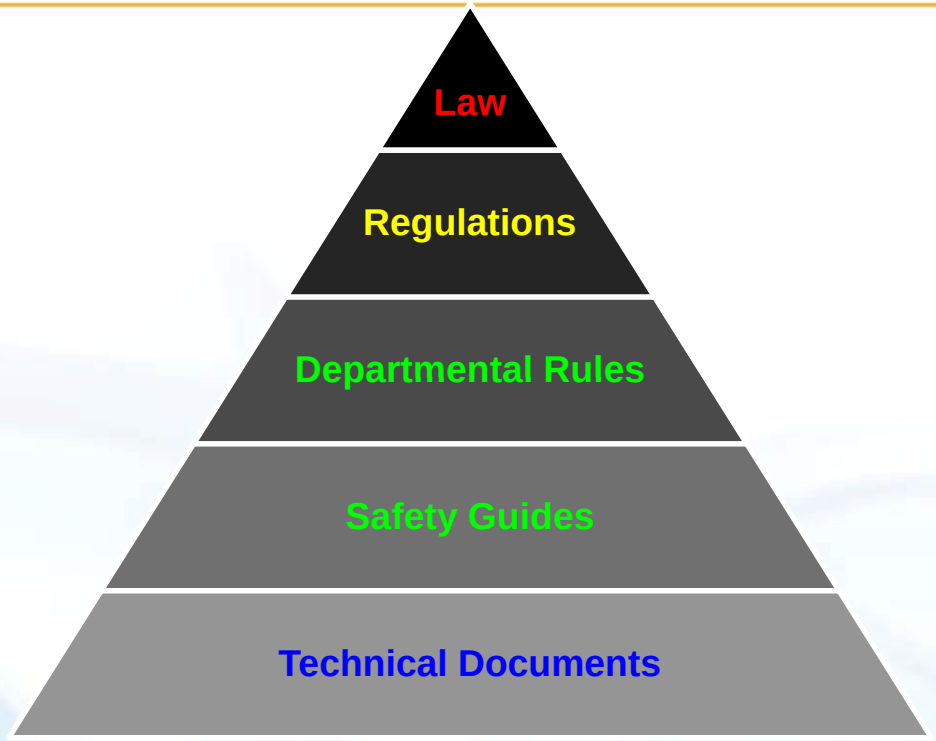
User Requirements of INPRO Experience

User requirement UR1: An adequate legal framework should be established to cover the issues of nuclear liability, safety and radiation protection, environmental protection, control of operation, waste management and decommissioning, security, and non-proliferation.

Criterion CR1.1 legal aspects

Indicator IN1.1: Status of legal framework.

Acceptance limit AL1.1: Legal framework has been established, in accordance with international standards.



In China, five levels of codes or standards are established. Regulations and departmental rules are conform with IAEA's safety requirements. Safety guides are conform with IAEA specific safety requirements as , Technical documents is conform with IAEA TECDOC. All power reactors, including ACP100 uses the same rules and guides.

Criterion CR1.2 institutions

Indicator IN2: Status of State organizations with responsibilities for safety and radiation protection, environmental protection, control of operation, waste management and decommissioning, emergency preparedness and response, security, and non-proliferation.

Acceptance Limit AL1.2: State organizations have been established, in accordance with international standards.

In China, National Nuclear Safety Authority is responsible for safety and radiation protection, environmental protection, control of operation, waste management and decommissioning.

China Atomic Energy Agency is responsible for emergency preparedness and response, security, and non-proliferation.

Minimization of infrastructure (UR5)

Reductions of necessary infrastructure could have been achieved by reducing the necessary human resources to operate, maintain and repair the new nuclear facility, and during construction of a nuclear facility by using prefabrication of components.

In the initial design of ACP100, major components, such as reactor vessel, internal OTSG can be welding in the factory and transport to the site together thus shorten the manufacture and installation time

User requirement UR5: The nuclear energy system should be designed to minimize the necessary infrastructure.

Whether the designer has succeeded in reducing the necessary infrastructure needed for a new facility in comparison to an existing (or reference) facility.

The major components of ACP100 are manufactured by the same factory of large nuclear power components suppliers. For examples, The fuel assembly, the control drive mechanism, reactor vessel and reactor internals

A technology user as the INPRO assessor is assumed to prefer proven designs of nuclear facilities to be installed in his country, i.e. designs that do have an existing reference facility already licensed and in operation.

For FOAK SMR, it is difficult to find a suitable reference facilities but most of the components of ACP100 have its operation experience in the past large nuclear power plant, for example, pumps, valves and pipes, they are using the same technology but different size, dimension and power. The supplies of these components can provide the past operation feedback information.

The innovations in the ACP100 NES (or facility thereof) decrease the need (and cost) for various parts of the infrastructure. As an example, the OTSG of ACP100 is a highly reliable component significantly reduced maintenance.

With its less source term and higher safety, ACP100 technically would not need large emergency preparedness facilities or a large exclusion zone.

With its relative large inventory in the reactor vessel, ACP100 has very slow transients that could be monitored remotely, would reduce the need for corresponding infrastructure.

The first aspects of ACP100 is reduce manufacture time. The extent to which prefabrication of components can be utilized to reduce construction works. Some major components of ACP100 can be manufactured and assembled in the same factory and transported to the site at the same time.

The second aspect is related to the amount of work to be performed during the construction and erection of the facility. With modular design, with modular nuclear steam supply system by the merit of integrated design could decrease the amount of human resources and some equipment needed at the construction site.

IN CONCLSION

INPRO has formulated three criteria for UR5 covering the aspects discussed above as follows.

User requirement	Criteria	Indicators (IN) and Acceptance limits (AL)
UR5 Minimization of infrastructure: *The nuclear energy system should be designed to minimize the necessary infrastructure.*	**CR5.1:** Personnel	**IN5.1:** Manpower needed for operation, maintenance and repair, and decommissioning. **AL5.1:** Amount is reduced in comparison to an existing facility[70].
	CR5.2: Prefabrication	**IN5.2:** Extent of prefabrication of components. **AL5.2:** Extent is increased in comparison to an existing facility.

IN CONCLSION

- ***For ACP100 and most of the small modular reactors, the main control room can be used for two or more reactors thus reducing the necessary human resources.***
- ***For ACP100 and most of the small modular reactors, the civil structure can prefabricated in the factory and transport to site thus reducing the necessary human resources.***